Analysis of the relationship between Modic change and spinopelvic alignment parameters in degenerative scoliosis patients

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Research article

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Abstract

Background: Sagittal alignment and coronal balance have been considered to be important in treating patients with degenerative scoliosis (DS). Previous studies have reported that Modic changes (MCs), disc degeneration (DD),and facet tropism(FT) have been considered as major factors forspinopelvic alignment parameters inpatients with DS. However, no previous study has investigated relationship between them.

Methods: Our retrospective study recruited 38 DS patients and41 healthy age and sex matched individuals.The DS patientswere divided into DS group andhealthy age and sex matched individuals were divided into healthy group.Full-length frontal and lateral views of the entire spine was measured to evaluate sagittal alignment and coronal balance. Endplate-disc-facetjoints degeneration of patients with DS were quantified using the Modic classifications, DD, and FT.The spinopelvic alignment parameters were measured, including pelvic incidence,sacral slope,lumbar lordosis, thoracic kyphosis, C7-sagittal vertical axis, L3 tilt, coronal balance distance, coronal cobb angel, thoracolumbar junctional angle, T1 pelvic angle.

Results: Based on radiographic findings, the incidence of MCs at different lumbar level was higher percentage of participants showed MCsand FT in the DS group (DS group: 52.63%, healthy group: 11.24%). The coronal and sagittal parameters were significantly different between DS group and healthy group ($p<0.05$), except for SS (>0.05).Besides, there was significant correlation between the coronal and sagittal parameters.

Conclusions: Coronal deformity has little effect on sagittal parameter sexcept for SVA, TK, and LLI. Besides, differentcoronal deformity types show weak difference on sagittal plan. The prevalence of MC in DLS group is higher than healthy group, which result in poorer clinical outcomes.

Introduction

Degenerativescoliosis (DS) become anincreasing healthcare concern owing to an aging population[1]. Surgical treatment achievesbetter health statusandimproves imbalance of the spine in thesagittal and coronal planes[2].Sagittal imbalance is reportedto be associated with low health-related quality of life (HRQOL)[3].Coronal imbalance, which has been reported to be associated with a HRQOL recently, has become an imaging feature of impaired function and back pain[4].

It has been reported that DS was triggered by asymmetrical fact joint degeneration [5]and DD[6]. Asymmetric facet joints degeneration, namely FT, has been reportedtolead to degenerative changes, such as degenerative spondylolisthesis[7].The relationship between facet jointsorientation, the intervertebral disc herniation, and degenerative spondylolisthesis have been wellexamined[8]. However, no literature has investigated the relationship between them and DS. The facet jointsandintervertebral disc are complex structures stabilizing the spinal motion segments[9]. The facet joint and intervertebral disc bear segmental loads making it prone to degeneration.Asymmetric changein loading of the segment lead to instability of lumbar spinal column that leads to vertebral rotation or spondylolisthesis. The asymmetricthe facet jointsand DD at each spine level triggers progression of exacerbated curve.The progressing curvature magnitude and facet joints degeneration havebeenidentifiedasfactorsrelated with the severity of clinical symptoms [10]. What´s more,tsutomu et al. reported that MCs were associated with the magnitude of lumbar coronal curve[11]. Severalstudies elucidated that progression of MCs was connected with a coronal deformity of the lumbar spine[12].

The endplate plays a key role in mechanical environment, hydrostatic pressure, and nutritional pathway,which are considered to be vital for preventing discdegeneration[13]. Recent research has shifted to role of endplate defects in progressionofdisc degeneration pathology.Therefore, both MCs and DD are associated with the vertebra instability.The MCs and the DD involve multifactorial process and act as an interacting unit, which altered mechanical behavior of the spine.Further, several reports demonstrated that theFT was related with the vertebra instability[14, 15].Hence, we speculate that progression of MCs, DD, and FT may promote occurrence of lumbar vertebra instability, and patients with MCs, DD, and FT may have different spinopelvic alignment parameters compared with subjects without MCs, DD, and FT. To our knowledge, we are the first to explore the the prevalence of MCs, DD, and FT and the relationship amongthem and spinopelvic alignment parameters on both coronal and sagittal planesinpatients with DScompared with healthy controls.

Methods

This study retrospectively evaluatedradiographical dataof 50 subjectswith DSfrom the First Hospital Affiliatedwith Nanjing Medical University and The Affiliated People's Hospital with Jiangsu University. from January 2011 to December 2017.Radiographical data includedfull-spine posteroanterior and lateral radiographs, MRI and CT. The inclusion criteria were: (1) subjects older than 50 years; (2) subjects with degenerative scoliosis, defined by a Cobb angle greater than 10° in the coronal plane; (3) no history of previous orthopedic surgery. The exclusion criteria were: (1) without complete radiological data; (2) metabolic spinal pathology; (3) infection; (4) history of spinal trauma; (5) missed follow-up visit.11 subjects who were not meet the inclusion criteria were excluded.38subjects (26 females and 12 males) aged 32 to 80 years (mean age: 63.92 ± 12.67 year)were enrolled.The study was approved by the Ethics Committee of The Affiliated People's Hospital with Jiangsu University.

Radiographic Measurements

The spinopelvic alignment parameters in the coronal and sagittal plane were measured on lateral and frontal views of full-length standing radiography using the picture archiving computer-analysis system (PACS) system by two spinal surgeons. Parameters in the coronal plane included coronal cobb angel, L3 tilt, coronal balance distance. Spinopelvic sagittal alignment parameters included pelvic tilt, pelvic incidence, sacral slope, lumbar lordosis, thoracic kyphosis, thoracolumbar junctional angle, T1 pelvic angle, C7-sagittal vertical axis.

Pelvic tilt (PT): the angle between the line through the midpoint of the sacral plate to femoral heads axis and the vertical line. Pelvic incidence (PI): the angle subtended by a perpendicular from the upper endplate of S1 and a line connecting the center of the femoral head to the center of the upper endplate of S1. Sacral slope (SS): the angle between a horizontal reference line and a line drawn parallel to the sacral endplate. Lumbar lordosis (LL): cobb angle from the lower endplate of S1 to the upper endplate of L1. Thoracic kyphosis (TK): the inferior end plate of C7 to the inferior end plate of T12. C7-Sagittal vertical axis (C7-SVA): distance between the C7 plumb line and posterior superior corner of the S1 body. L3 tilt (L3T): the angle between horizontal reference line and the upper endplate of L3.Coronal balance distance (CBD): distance between C7 plumb line and the center sacral vertical line. Coronal cobb angel (CCA): the angle between the caudad end vertebra's inferior surface and the cephalad end vertebra's superior surface. Thoracolumbar junctional angle (TLJA): the angle between the T11 superior end plate to L1 inferior end plate. T1 pelvic angle (TPA): the angle between the line from T1 to femoral heads and the line from femoral heads to the center of S1 endplate. All measurement was performed by three individual surgeons. (Fig. 1)

Assesement Of Modic Changes

MCs was defined as the presence of high or low signal at the vertebral body levels L1-S1andwas categorized into three types according to the signal intensities on midsagittal views of MRI. Classification of MCs was shown in Table 1. The presence of MCs was recorded without specifying the subtype.

Assesement Of Facet Tropism

The facet tropism was evaluated at each level of lumbar on the CT. a line through the posterior edge of the vertebral body was defined as M. A sagittal line perpendicular to M through the spinous process was defined as N. Facet joint orientation was defined as angel between a line drawn though the margins of the facet joint and N. FT was defined as the absolute value of difference between the right angle and the left angle. (Fig. 2)

Statistical Analysis

We performed statistical analyses using SPSS (version, 21.0 SPSS Inc, Chicago, IL). Mann-Whitney U test or chi-square test was used to compare parameters between groups. We calculated the correlation between the coronal and sagittal parameters with Spearman's correlation test. The subjects were grouped based on gender, BMI, MC, and facet tropism, one-way ANOVA test test were used to assess the disparities among different groups. P less than 0.05 was considered statistically significant.

Results

All spinopelvic alignment were similar between different gender, age, and BMI in FT<10 degrees group and FT ≥10 degrees group(p<0.05). (Figure 3)

SVA, L3 tilt, and CBD was different at T12/L1 level but other sagittal parameters were comparable(P<0.05); all parameters were similar at L1/2 level; TLJA was different between at L2/3 level while other sagittal parameters were similar(P<0.05); all parameters were similar at L1/2 level; TPA was different between at L4/5 level but other sagittal parameters were comparable(P<0.05); all parameters were similar at L5/S1 level.(P<0.05, Figure 4).

The coronal parameters and sagittal parameters at different levels preoperatively between 2 groups were shown. (Figure 4)

A total of 42 endplates in 38 degenerative scoliosis patients showed MC on MRI scans. 7 L1/2 segments (16.66%), 6 L2/3 segments (14.28%), 9 L3/4 segments (21.42%), 10 L4/5 segments (23.80%), 10 segments of L5/S1 (23.80%). (Figure 5)

There was significant difference in coronal parameters and sagittal parameters between DS group and control group, except for SS (P<0.05). (Table 2)

The SS was different between MCs group and without MCs group at L1/2 level (P<0.05); the PI was different between MCs group and without MCs group at L2/3 level (P<0.05); the Coronal cobb was different between MCs group and without MCs group at L3/4 level (P<0.05); the SS and SVA were different between MCs group and without MCs group at L4/5 level (P<0.05); the PI and SS were different between MCs group and without MCs group at L5/S1 level (P<0.05).

Correlation analysis of column-pelvis radiographic parameters indicated that PT was positively correlated with PI, SS, TK, LLI, TLJA and TPA (r=0.622, -0.387,-0.371,-0.509,-0.326, and 0.523respectively, P<0.05);PI positive correlated with the SS and TPA(r=0.477, 0.457respectively,P<0.05); SS was associated with LL, TK, and LLI (r=0.540, 0.418, and 0.364respectively, P<0.05); LLI and TPA were highly correlated with LL (r=0.887, -0.430respectively,P<0.05);TK was associated with LLI and TLJA (r=0.344 and 0.384respectively, P<0.05); LLI was associated with TLJA and TPA (r=0.386 and -0.609respectively, P<0.05); L3 tilt was associated with TLJA (r=-0.342, P<0.05);CBD was associated with SVA and TPA (r=0.360 and 0.338 respectively, P<0.05);SVA was associated with TPA (r=0.471, P<0.05). (Figure 6 and Table 4)

Discussion

Relationship Between Modic Changes And Ds

Our study showed that the prevalence of MCs (52.63%) of our study was higher than that of the previous study (5.8 ~ 22.4%). The main reason is that elderly patients recruited in our study had a certain degree of DS, which would increase the incidence of MCs. In addition, the differences in the reported prevalence across different studies could be explained by the differences in determinants of MCs.

We also found most of DS patients with MCs had low back pain, which resulted from MCs and intervertebral disc. We therefore analyze the distribution of MCs in the assessment of pain for patients with DS. We found that there was a significant association between MCs and spinopelvic alignment. The patients with DS may often have overload force caused by crouching motion, which would cause MCs and the intervertebral disc degeneration. The measurement of coronal and sagittal parameters can help to determine the prognosis of spinal degeneration diseases. So, the relationship between coronal and sagittal parameters of DS and spine degenerative changes is important. Our results showed that the incidence of MCs in DS was strongly correlated with PI, SS, SVA, and coronal cobb at different level. The correlation between MCs and DS may be due to the increased shear force of endplate and decreased axial decompression ability of the lumbar spine. The degree of injury caused by the external force in the perpendicular direction depends on the degree of structural degeneration of the vertebral body. We supposed that the incidence of MC is positive correlated with severity of scoliosis and facet joint asymmetry. However, it was unclear whether MCs was the cause or effect of the scoliosis. Biomechanical balance disorder increases shear forces between adjacent vertebral bodies, which will cause the generation of different types of MC[16]. MCs also reverses as the biomechanical balance return to normal.

Still further, FT could worsen the deformity of endplate and cause the disc imbalance and instability which eventually lead to the expansion of degenerative scoliosis. Therefore, MCs produced DS with intervertebral instability as a mediator. Conversely, the asymmetrical endplate load caused by scoliosis could aggravated progression of MCs.

Relationship Between Facettropism And Ds

Asymmetrical degeneration of discs and asymmetrical facet joints orientation produce lateral and rotational deformity, which have been implicated as pathogenesis factors in the progression of DS, Lumbar facet joints. No previous research stated initiating factors of these change. Our results showed that coronal and sagittal parameters in patients with DS was different between FT < 10 degrees group and FT ≥ 10 degrees group. We didn't figure out whether the FT caused the DS, or DS caused the FT. We hypothesis that the vertebral disc and the facet joints have mutual influence and are trapped in vicious circle with the degeneration of the whole spine.

The results of this study showed that FT was related to coronal and sagittal parameters at different levels(Fig. 3). Rankine reported that FT would increase the force through one side of the spine, causing degenerative spinal diseases [14].Kim et al. demonstrated that facet joint tropism would make the segment vulnerable to anterior shear force or external moments [17]. Do et al. reported a severe FT in patients with progressive facet arthritis[18]. Our results indicated that FT would increase lateral instability and proposed that FT was responsible for DS. FT played a vital role in evaluating curve progression, a careful analysis of transverse CT scans in patients with DS would be helpful in predicting the natural history of DS. In addition to FT, we found that L3 tilt and coronal cobb angle were significantly related with FT according to logistic regression. In consistent with our results, Liu et al. reported an association between coronal spinopelvic parameters and degenerative lumbar scoliosis[19]. A larger Cobb angle would tilt the space between the vertebra below and the apex. In this process, an increased lateral sliding force would aggravate the disc degeneration.

Relationship Between Coronal Parameters And Sagittal Parameters

As a severe spinal deformity, DS manifests as a three-dimensional deformity which involve coronal, sagittal and mixed. Previous studies have focused on sagittal balance because the incidence of sagittal imbalance in patients with DS was as high as up to 34.8% [20, 21]. However, several reports confirmed that coronal balance was related with radiculopathy and claudication gait, which play an important role in progression of DS.

Our results showed that there was a correlation between coronal and sagittal in the DS patients (Table 4). We believe that the coronal and sagittal malformations have similar developmental processes. However, no correlations between CBD, coronal Cobb angel, and TLJA were found. This result confirmed that sagittal balance was partly restored by TK aggravation and pelvic retroversion because SVA was still beyond the normal range.

Limitations

Despite the strengths, several limitations could not be avoided. First, this study did not record MCs in all thoracic vertebrae, which could be improved by enrolling a large number of subjects, Second, the types of DS are diverse and the degenerative changes were associated to many factors.

Conclusion

Our results showed that the MCs were most observed at the level ofL3/4, L4/5 and L5/S1. MCs and FT were strongly correlated with coronal and sagittal parameters. So, for the patients with DS, we should pay attention to the distribution of MCs and FT in order to guide the prognosis and treatment. However, the spinopelvic alignment parameters were similar in both gender, age, and BMI. The minority of coronal parameters had an influence on sagittal parameters. So, the related risk factors remain to be further investigated.

Abbreviations

PT:Pelvic tilt; PI:Pelvic incidence; SS:Sacral slope; LL: Lumbar lordosis; TK:Thoracic kyphosis; C7-SVA: C7-Sagittal vertical axis;L3T:L3 tilt; CBD: Coronal balance distance ; CCA:Coronal cobb angel; TLJA:Thoracolumbar junctional angle; TPA:T1 pelvic angle; DS:degenerative scoliosis; MCs:Modic changes; DD: disc degeneration; FT: facet tropism

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the The Second Hospital of Jilin University; due to the retrospective nature of the study, the need for informed consent was waived.

Consent for Publication

Not applicable.

Availability of data and material

All data has been showed in tables and picutres.

Competing interests:

The authors declare that they have no conflict of interest.

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No

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Tables

Table 1.Modic classification: MRI changes and associated pathological features

Vertebral endplates	T1-weighted sequences	T2-weighted sequences	Histopathology
Modic 1	Hyposignal	Hypersignal	Oedema, inflammation
Modic 2	Hypersignal	Isosignal or hypersignal	Fatty changes
Modic 3	Hyposignal	Hyposignal	Fibrous process

Table 2.Pemographics of degenerative kyphoscoliosis patients

Number of cases	Gender (M/F)	Age (yrs)	PT	PI	SS	LL	TK	TLJA	TPA	C7-SVA
50	15:35	65.02±11.84	42.85±11.31	11.61±6.23	31.24±12.59	45.46±14.2	29.78±11.7	13.06±10.63	21.37±9.71	53.7±32.67

Note: Values are present as mean (standard division).

Abbreviations: PT, Pelvic tilt; PI, Pelvic incidence; SS, Sacral slope; LL, Lumbar lordosis; TK, Thoracic kyphosis; TLJA, Thoracolumbar junctional angle; TPA, T1 pelvic angle; C7-SVA, sagittal vertical axis.

Table 3.Comparision between spinopelvic alignment parameters of MCs group and none-MCs group in degenerative kyphoscoliosis patients

	Modic L1/2			
	none-MCsgroup（n=19）	MCs group（n=9）	t	p
SS (°)	30.13±8.56	20.6±9.89	2.620	0.014*

	Modic L2/3			
	none-MCsgroup（n=19）	MCs group（n=9）	t	p
PI (°)	50.16±12.62	41.8±6.8	2.275	0.032*
	Modic L3/4			
	none-MCsgroup（n=14）	MCs group（n=14）	t	p
Coronal cobb (°)	10.89±5.73	21.94±12.89	2.931	0.009*

	Modic L4/5			
	none-MCsgroup（n=10）	MCs group（n=18）	t	p
SS (°)	33.62±9.26	23.43±8.46	2.955	0.007*
SVA (mm)	72.88±28.83	46.38±31.92	2..176	0.039*

	Modic5/S1			
	none-MCsgroup（n=11）	MCs group（n=18）	t	p
PI (°)	54.88±12.01	42.85±8.53	3.156	0.004*
SS (°)	33.82±8.42	23.11±8.31	3.350	0.002*

Table 4. Correlations between spinopelvic alignment parametersandModicchange among the DS patients

		PT	PI	SS	LL	TK	LLI	L3Tilt	CBD	SVA	TLJA	TPA	Coronal cobb
PT	R	1	0.622	-0.387	-0.226	-0.371	-0.509	0.115	0.269	0.134	-0.326	0.523	0.267
	P		0.000*	0.016*	0.172	0.022*	0.001*	0.492	0.102	0.423	0.046*	0.001*	0.105
PI	R		1	0.477	0.245	-0.011	-0.176	0.083	0.099	0.244	-0.214	0.457	0.172
	P			0.002*	0.139	0.948	0.290	0.622	0.554	0.139	0.197	0.004*	0.302
SS	R			1	0.540	0.418	0.364	-0.007	-0.203	0.097	0.115	-0.052	-0.073
	P				0.000*	0.009*	0.024*	0.966	0.221	0.564	0.491	0.758	0.663
LL	R				1	0.308	0.887	0.030	-0.204	-0.202	0.175	-0.430	-0.061
	P					0.060	0.000*	0.857	0.218	0.224	0.292	0.007*	0.718
TK	R					1	0.344	-0.109	-0.078	0.067	0.384	0.033	-0.218
	P						0.035*	0.516	0.640	0.692	0.017*	0.843	0.189
LLI	R						1	-0.037	-0.209	-0.248	0.386	-0.609	-0.153
	P							0.824	0.209	0.134	0.017*	0.000*	0.359
L3 tilt	R							1	0.185	0.056	-0.342	0.269	0.193
	P								0.266	0.738	0.036*	0.102	0.244
CBD	R								1	0.360	-0.249	0.338	0.220
	P									0.027*	0.132	0.038*	0.185
SVA	R									1	-0.003	0.471	0.028
	P										0.985	0.003*	0.868
TLJA	R										1	-0.235	-0.149
	P											0.155	0.372
TPA	R											1	0.155
	P												0.354
Coronal cobb	R												1
	P												

Abbreviations: PT, Pelvic tilt; PI, Pelvic incidence; SS, Sacral slope; LL, Lumbar lordosis; TK, Thoracic kyphosis; TLJA, Thoracolumbar junctional angle; TPA, T1 pelvic angle; C7-SVA, sagittal vertical axis; CBD, Central sacral vertical line distance.

Figures

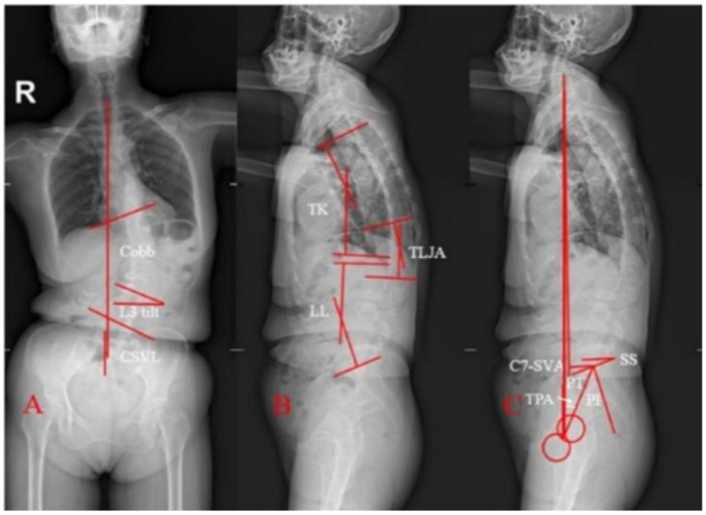


Figure 1

Measurement of coronal andsagittal parameters.

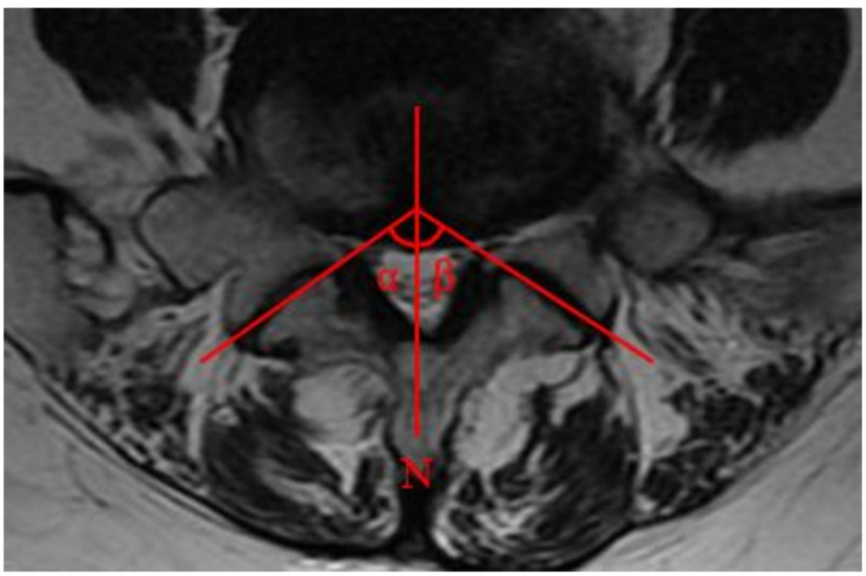


Figure 2

Method offacet tropism measurement. A midsagittal line crossing the center of the disc and the tip of the spinous process was drawn (N). A facet line connecting the anteromedial and posterolateral points of left (or right) facet was also drawn. FT was the angle between the facet line and the midsagittal line (αorβ).

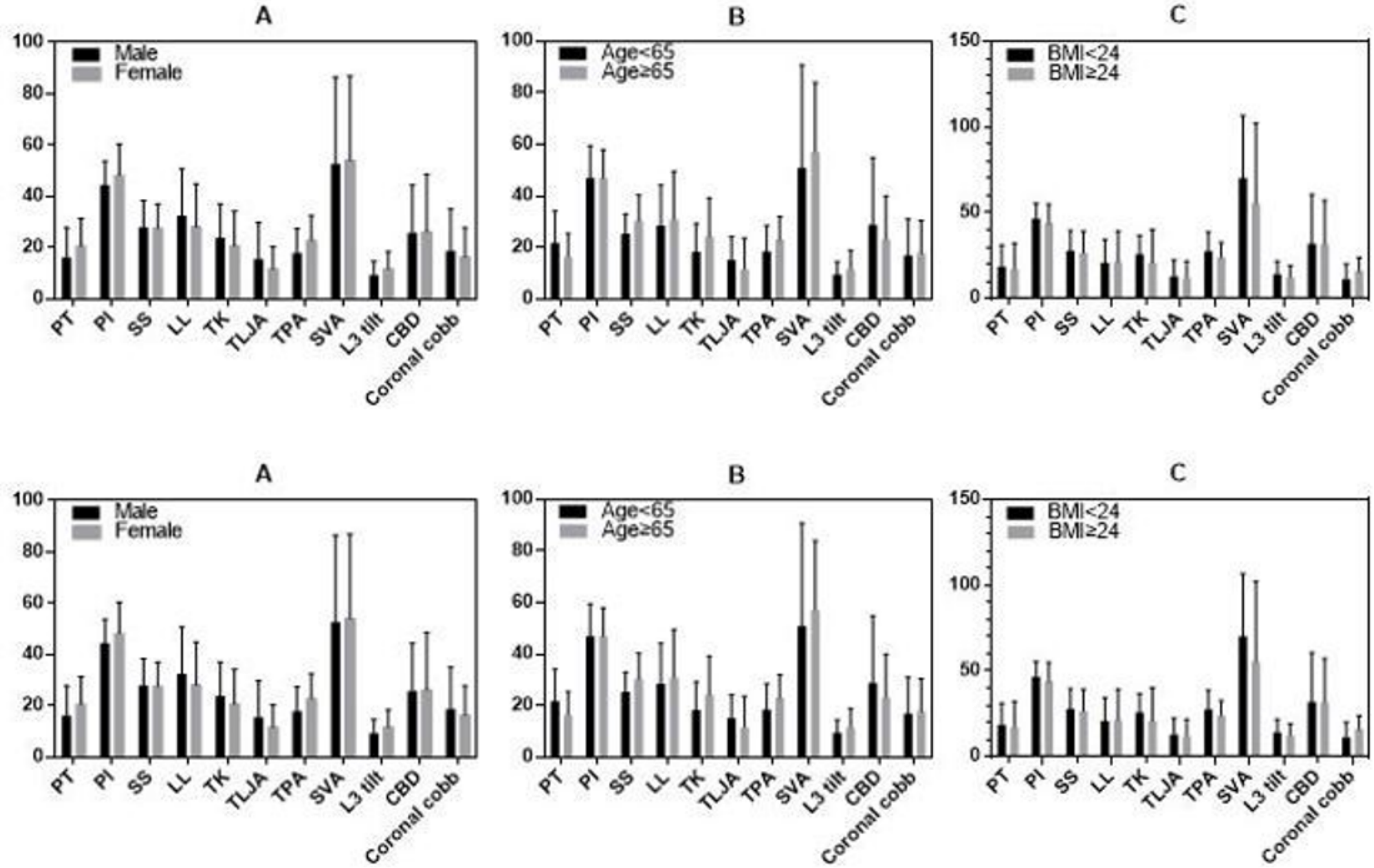


Figure 3

Comparison of sagittal parameters accordingtodifferent groups. A.All parameters were similar between males and females, B. All parameters were similar between different age, C. Allparameters were similar between different BMI, *Statistically significant at P<0.05. One-way ANOVA test

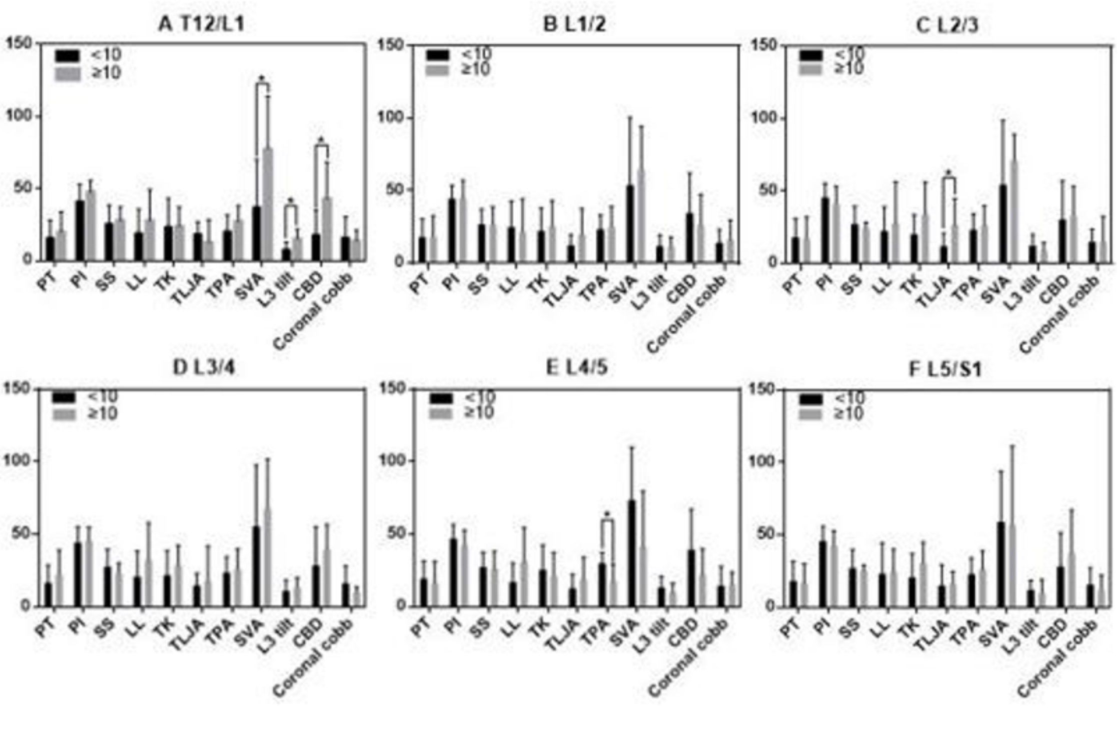


Figure 4

Comparison of sagittal angular parameters between FT<10°group and FT ≥10°group. A. SVA, L3 tilt, and CBD was different at T12/L1 level but other sagittal parameters were comparable, B.all parameters were similar at L1/2 level, C. TLJA was differentbetween at L2/3 level while other sagittal parameters were similar, D. all parameters were similar at L1/2 level, E. TPA was differentbetween at L4/5 level but other sagittal parameters were comparable, F. all parameters were similar at L5/S1 level. *Statistically significant at P<0.05. One-way ANOVA test

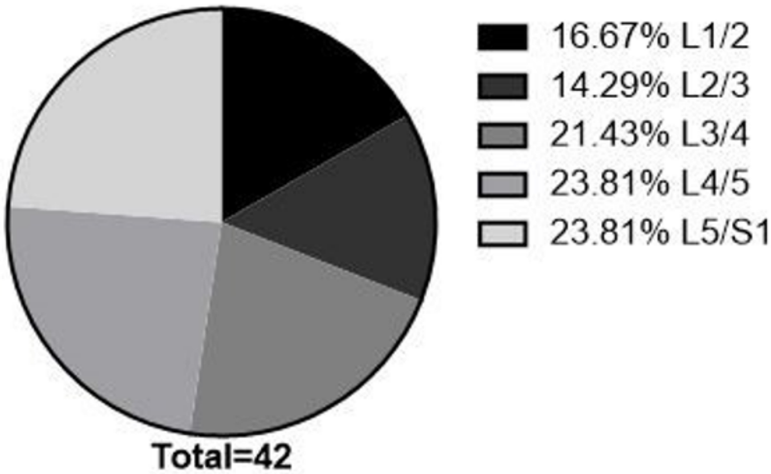
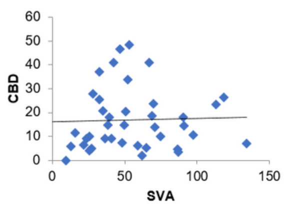
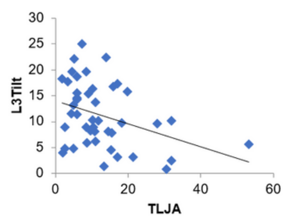


Figure 5

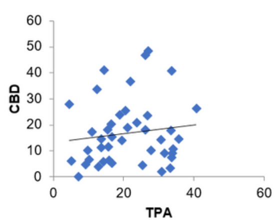
Distribution of MCs in different levels.

A

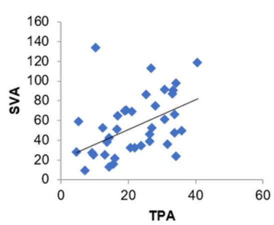




B



C



D

Figure 6

linear regression analysis of coronal parameters and sagittalparameters. Note: (A–D) linear regression analysis comparing CBD and SVA, L3 tilt and TLJA, CBD and TPA, and SVA and TPA, respectively. Abbreviations: CBD,Coronal balance distance; SVA, Sagittal vertical axis; TLJA, Thoracolumbar junctional angle; TPA, T1 pelvic angle.